Developing national CCS capacity and advanced skills

Available online at www.sciencedirect.com

SciVerse ScienceDirect

Energy Procedia 37 (2013) 7281 – 7290

Energy Procedia

GHGT-11

Developing national CCS capacity and advanced skills: Examples from the UK

Robin Cathcart[a]*, Hannah Chalmers[ab], Colin Snape[ac], Elizabeth VanderMeer[a], Jon Gibbins[ab]

[a] UK CCS Research Centre, King's Buildings, Mayfield Road, Edinburgh EH9 3JL, UK
[b] Scottish Carbon Capture & Storage, School of Engineering, University of Edinburgh, King's Buildings, Edinburgh EH9 3JL, UK
[c] University of Nottingham, Faculty of Engineering, University Park, Nottingham NG7 2RD, UK

Abstract

Rapidly training researchers involved in carbon capture and storage (CCS) and advancing fundamental understanding of the entire chain is vital to achieve CCS deployment in a timescale aligned with global emission reduction targets. This paper introduces a number of initiatives that are building UK CCS capacity, focussing on activities involving the academic community such as the UK CCS Research Centre (www.ukccsrc.ac.uk) and a number of postgraduate training programmes. These and other examples illustrate the benefits associated with academic-industry collaboration, as well as providing valuable opportunities to accelerate development of suitably trained people and CCS technology in an academic context.

Selection and/or peer-review under responsibility of GHGT

Keywords: carbon capture and storage; CCS; developing capacity and skills; research centre

1. Introduction

The UK academic community has a long track record in CCS research [e.g. 1] and this is complemented by early identification of CCS as a potentially cost-effective approach to mitigating the risk of dangerous climate change by UK policy-makers. [2,3] A step-change in UK (and global) research activity in CCS occurred in 2005 when the G8 met at Gleneagles, Scotland, and formally endorsed CCS.

* Corresponding author. Tel.: +44 (0) 131 650 8564
E-mail address: ukccsrc@ed.ac.uk.

1876-6102
Selection and/or peer-review under responsibility of GHGT
doi:10.1016/j.egypro.2013.06.666

2005 also saw the Intergovernmental Panel on Climate Change (IPCC) publish an authoritative special report entitled "Carbon Dioxide Capture and Storage."[4]

As CCS was rising up the international agenda during the early and mid 2000's, a number of additional members of the UK academic community began to work in the field of CCS, including as part of the 14-partner UK CCS Consortium from 2005 to 2009.[5] The Consortium was funded through the Natural Environment Research Council (NERC) as part of the Research Councils UK (RCUK) 'Towards a Sustainable Energy Economy' programme and successfully established a multidisciplinary CCS research base in the UK.[5, 6] It has been followed by several more specialised multi-partner consortia and the UK CCS Community Network. This follow-on Network was funded in 2009 by the Engineering and Physical Sciences Research Council (EPSRC) as part of the RCUK Energy Programme with core aims that included helping the UK research community stay in touch with each other and providing a 'one stop shop' for key stakeholders to get rapid access to the UK CCS academic research community.

Alongside this academic growth, since 2005, the UK and international low carbon energy agenda has increased focus on CCS as a potentially vital and low cost technology to mitigate greenhouse gas emissions. The IEA's 2009 Technology Roadmap for CCS targeted global CCS projects to number 100 by 2020 and around 3400 by 2050.[7] Although much of the focus of early CCS activity has been on mitigating CO_2 emissions from power plants, CCS is also likely to be important for reducing industry greenhouse gases. For example, in the UK the Committee on Climate Change has estimated that around 20% of UK industry emissions could be avoided with CCS.[8]

A long-term and strong commitment to a diverse R&D community to develop both technology and skilled people able to address the opportunities and challenges associated with successfully deploying commercial-scale CCS is likely to make a significant contribution to identifying and developing effective approaches for designing and delivering CCS projects. The UK has understood the need for this commitment and the majority of major funders of energy research in the UK now have CCS projects in their portfolio. This includes substantial investment in the academic community by the RCUK Energy Programme and also in industry-led projects by the Technology Strategy Board (TSB) and the Energy Technologies Institute (ETI). UK CCS R&D capacity has, therefore, steadily increased in response to increased availability of funding for academic work, alongside 'real world' progress.

An important recent development was the launch of UK CCS Research Centre (UKCCSRC) in April 2012, supported by EPSRC as part of the RCUK Energy Programme, with additional funding from the UK Department of Energy and Climate Change (DECC). The aim of the UKCCSRC is to provide a national focal point for CCS research and development in order to bring together the user community and academics to analyse problems, devise and carry out world-leading research and share delivery, thus maximizing impact. A key priority is to help stimulate the UK economy by driving an integrated research programme focused on increasing the contribution of CCS to a low-carbon energy system for the UK (and globally).

This paper introduces some examples of approaches to developing UK advanced skills and capacity in CCS and highlights some lessons learned. Section 2 focuses on developing and implementing a high impact, co-ordinated research agenda for the academic community and Section 3 discusses activities targeted at early career researchers.

2. Co-ordinated research activities

The UK energy funding landscape is somewhat complex, with funding for different aspects of technology development typically provided by different funding bodies. The RCUK, a strategic partnership of seven subject-specific Research Councils, provides core funding for many academic activities in the UK. Within RCUK, five Research Councils, led by EPSRC, have developed the RCUK Energy Programme, which is leading on CCS funding for the UK academic community. In 2012, EPSRC's Energy Programme is supporting over £38 million in active grants for nearly 40 research and capacity building project in CCS, with the stated goal of maintaining this level of support for the foreseeable future. [9]

RCUK funding is complemented by resource available from a number of other research sponsors with more applied and industrial foci. The TSB, established in 2007 and sponsored by the UK Department for Business, Innovation and Skills (BIS) supports Knowledge Transfer Networks and specific research projects with CCS themes, such as the CCPilot100+ Project (Section 2.2). The ETI, which in October 2012 announced funding for a £20 million CO_2 capture project, to complement existing £33 million of investment in its CCS technology programme, is a public private partnership that, like TSB, supports nearer to market research with a more applied and industrial focus.[10] DECC has also given research a strong place in their overarching CCS strategy. DECC's CCS Roadmap, published April 2012, lays out a 4-year £125M coordinated R&D programme which supports approximately £40M in fundamental research and increased understanding, £30M in component development and innovation, and £55M in pilot-scale testing and projects.[11] Members of the UK academic community are engaging with all of these funders and many more, including international research funding partners and industry.

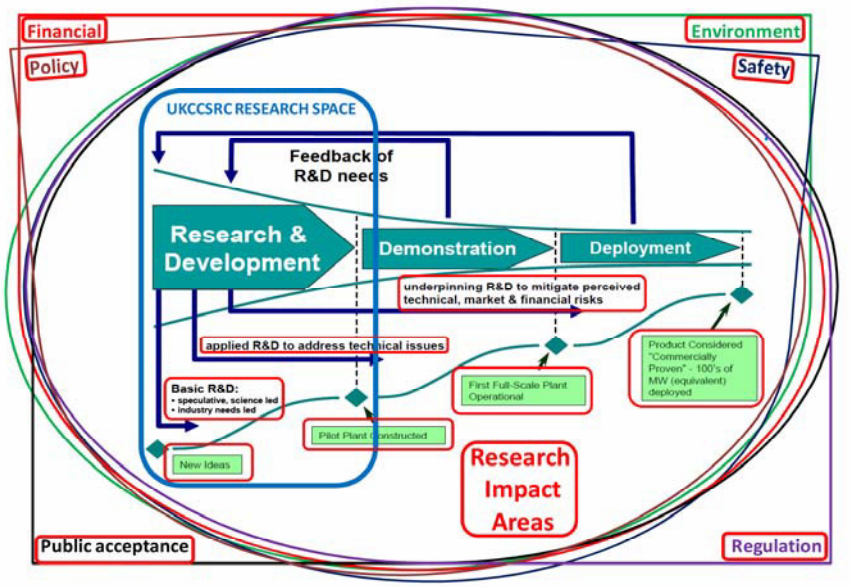

Figure 1 Illustrative outline of UKCCSRC research space and some potential areas for impacts from UKCCSRC research, within the CCS innovation chain but also throughout the whole CCS system
(CCS innovation chain from 'CATs R+D - an Industrial Viewpoint', Mike Farley, APGTF 8th CATS Workshop, 27 Feb 2008, http://www.apgtf-uk.com/files/documents/8thWorkshop2008/09JMFIndustryAPGTF%20Forum27Feb08.pdf)

As illustrated in Figure 1, the UKCCSRC aims to be a unifying organisation that is linked to all publicly sharable CCS research in the UK, thereby increasing knowledge exchange and delivering impact in a coordinated approach that addresses national research and development needs. It assists the academic community, industry and other stakeholders by delivering targeted research programmes on priority themes as identified by leading CCS industries. Biannual face-to-face UKCCSRC meetings and a range of specialist workshops and other events further contribute to national CCS knowledge exchange and provide a networking foundation for all UK CCS researchers across academe, industry and other stakeholder groups.

The rest of this section will focus on three examples where 'the sum is greater than the individual parts': the Pilot-Scale Advanced Capture Technology (PACT) shared facilities (Section 2.1); industry-academic collaboration within the CCPilot100+ project (Section 2.2) and the Research and Pathways to Impact Delivery (RAPID) process for developing a high-impact research programme (Section 2.3).

2.1 Pilot-Scale Advanced Capture Technology (PACT) Shared Facilities

Funding for the UKCCSRC from DECC and EPSRC included allocations for the purchase, relocation and operation of the Pilot-scale Advanced Capture Technology (PACT) shared facilities. PACT, situated in Beighton, Yorkshire is an integral part of the Research Centre's activities and an example of the extended capabilities that a UK-wide centre can support. As illustrated in Figure 2, the UKCCSRC PACT Shared Facilities offer, on one site, a unique set of pilot-scale combustion, gasification and post-combustion capture facilities that can be configured to operate in a wide range of modes and with a range of fuels. They will be a focal point for large scale experimental work in the UKCCSRC, providing an important link between lab and MW-scale industrial facilities, and also a resource that UK industry, especially SMEs, can use to develop and demonstrate products for the CCS supply chain.

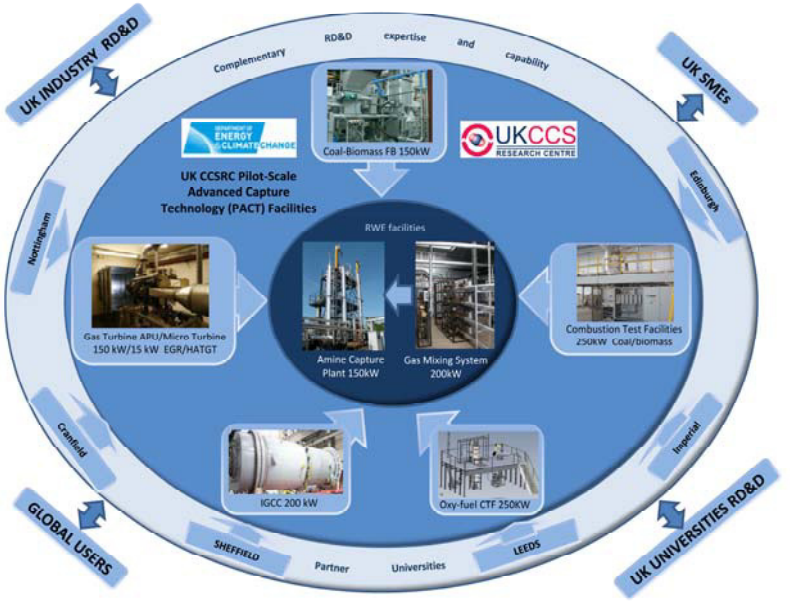

Figure 2 Overview of PACT facilities and partners

In the first half of 2012, a number of facilities were moved to the PACT site from RWE Npower (Didcot) including a 150kW amine capture plant, 200kW gas mixing facilities and a range of supporting facilities including large and small boilers for steam addition to the respective plants, gas heaters and power supplies. These are complemented by a new 150kW gas turbine and oxy-fuel combustion test facilities with state of the art non-intrusive laser diagnostic as well as conventional combustion gas, particulates, temperature, radiation and solid residual measurement devices. Also, in addition to the core PACT facilities at Beighton, Cranfield University is providing access to a range of its existing facilities as part of the UKCCSRC shared facilities activities, from industrial scale gas turbines to combustion rigs for gaseous, liquid and solid fuels. The University of Edinburgh is developing a facility for 'Advanced Capture Testing in a Transportable, Remotely-Operated Mini-lab' (ACTTROM) to test capture system components on site in real power plant flue gas slipstreams.[12]

2.2 Industry/academic collaboration in the CCPilot100+ Project

A successful example of linking academic and industrial research and development activity is the university programme included in the CCPilot100+ Project [13] located at Ferrybridge C power station in Yorkshire, UK. This pilot project is a joint venture of SSE, Doosan Power Systems, and Vattenfall, supported by DECC, the TSB and Northern Way. The unit, developed and constructed in just two years, was launched in early 2012 to capture 100 tons/day of CO_2 from coal (UK and imported) and biomass at the power station, which is two orders of magnitude larger than previous UK pilot units. It, therefore, provides an important stepping stone to larger-scale CCS demonstration.

CCPilot100+ is demonstrating the characteristics of a capture plant using real-time power plant flue gases, providing insights into operation and costs of CO_2 capture. It is also contributing to optimising the CO_2 capture process/components and developing performance models including process capability, stability, transient flexibility, amine degradation, and materials performance. Additionally, the project is supporting a series of activities to develop the UK skills base, with a programme of activities conducted with a group of partner universities that provides opportunities for exposure to the plant itself and also to undertake complementary research. Industry regulators, such as the Environment Agency of England and Wales and the UK Health and Safety Executive, are also learning from the project.

The programme of opportunities for exposure to the plant has allowed many students and other members of the academic community to gain an insight into commercial design and operation of CO_2 capture plants by providing a mixed programme of approximately 24 one-month secondments (typically undertaken by PhD students and postdoctoral researchers), one-week industrial awareness modules in carbon capture (which is particularly suitable for MSc students) and one-day workshops and visits (suitable for undergraduate students and others).

This mixed programme, complemented by targeted research activities that are taking advantage of the operational results of the CCPilot100+ test campaigns, have been mutually beneficial. Industry is stimulating relevant research in academe and motivating the potential recruits of the future. The academic community is enjoying a unique opportunity to gain first-hand experience of an operating CO_2 capture plant, allowing them to place their work in context and increasing the potential to deliver maximum impact for research.

2.3 Research and Pathways to Impact Delivery (RAPID) Process

For the UK CCS Research Centre to be truly successful at delivering impact, it must link world-leading research with impact from the outset. The Research and Pathways to Impact Delivery (RAPID) process is being carried out to identify areas of research that will form the Centre's core strategic programme The RAPID process is overseen by leading UK researchers in CCS and involves active discussion with practitioners to identify what knowledge is needed to deliver CCS applications ,both near- and longer-term to facilitate CCS commercialisation in the UK, the level of such know-how at present, and how to advance research in areas that are currently weak.

The formal output of this stakeholder engagement and input is in the form of the RAPID Handbook, which will be updated on an ongoing basis to allow the UKCCSRC to actively match its research priorities against national needs and technology development, including feedback from the commercialisation programme. [14]

The key questions RAPID aims to answer are:

What knowledge and related capacity will be needed to implement CCS?
To what extent is necessary knowledge and capacity already available to users?
How can gaps in knowledge be met?
How is knowledge made available to CCS practitioners (i.e. companies doing the work and government permitting and regulating the processes)?
What UKCCSRC-related capacity is required?
And how is this capacity created, maintained and delivered?

The first phase of RAPID began with a series of meetings, both formal and informal, with a wide range of CCS stakeholders under the coordination and leadership of 18 UKCCSRC Research Area Champions (RACs). RACs include many of the leading researchers in the UK across all applicable fields, and their practitioner engagement, leadership and direction have resulted in the production of application impact tables split out in a variety of themes spanning the CCS value chain. The application impact tables form the backbone of the Phase 1 RAPID handbook, which has culminated in an approximate £1.5M call for research proposals, to be awarded by the end of 2012. It is expected that the research funded through this first call will address priorities set out by CCS industry and government groups in the UK contributing to the Advanced Power Generation Technology Forum (APGTF) technology strategy for fossil fuel carbon abatement technologies [15].

Future iterations of the RAPID process will see an increasing emphasis on capacity building and the national research strategy will be further refined in 2013 with significant input from government and industries in the UK involved in the DECC CCS Commercialisation Programme. This increased granularity will allow a second phase of RAPID process to target specific areas deemed most important to the near-term commercialisation of CCS.

3. Developing early career researchers

A broad base community that is knowledgeable and skilled is essential for successful delivery of CCS R&D and deployment now and in the longer-term. There has been significant UK activity in universities and other research institutions to develop community's capacity. Here we will look at examples of

activities in postgraduate education and research (Section 3.1) and the role of the UKCCSRC Community Network in providing both networking and financial support for early career researchers (ECRs) to engage with other CCS researchers across the UK and abroad (Section 3.2).

3.1 Postgraduate education and research

A number of UK universities and research institutes are training increasing numbers of postgraduate students (e.g. MSc, PhD, EngD) working on CCS-related topics. As noted above, the UK has made a significant, ongoing contribution to CCS research output for several years, not least due to the efforts of the postgraduate student community. A full review of UK postgraduate training is beyond the scope of this paper. Instead, a few representative examples of university-based CCS education and training are introduced here.

In recent years, two UK postgraduate Masters programmes focusing on CCS and carbon capture and transport (CCT) have been developed. In 2009, the University of Edinburgh launched a one-year Master of Science (MSc) programme in CCS, the first of its kind in Europe.[16] The core curriculum includes competency in science and technology for CO_2 capture, transport and storage (both engineering and geological aspects), and a business background in climate change regulation and carbon commodities. The programme has graduated approximately 35 students, and expanded in 2011 to include a second "track" with a particular focus on power plant and CO_2 capture engineering. Cranfield University also started a one-year MSc programme in CCT in 2011.[17] The programme includes 10 compulsory modules in carbon capture technologies, carbon transport technologies, management for technology, risk and reliability engineering, process plant operations, power generation systems, process measurement systems, advanced control systems, process simulation and design, and computational fluid dynamics. The programme graduated 8 students in its inaugural year and plans to expand enrolment for future years. In addition to these two MSc programmes, various universities across the UK have deliver Masters programmes which include introductory material on CCS, with students graduating in a range of topics including energy, environment and carbon management.

A significant development in EPSRC-funded UK postgraduate training has been an increased use of focussed centres for doctoral training (CTDs) and co-funding of projects by industrial collaborators. Several CTDs with energy themes have been awarded to universities or groups of universities to bring together diverse areas of expertise to train engineers and scientists with the skill sets needed to address current and future energy challenges.[18, 19] CCS research is by no means limited to CTDs, however, and there are many universities across the UK with large cohorts of PhD and EngD students working across the value chain for CCS, with scopes ranging from highly focused to interdisciplinary.

One CTD which has been providing advanced training in CCS in recent years is an Engineering Doctorate (EngD) Centre in Fossil Energy and Carbon Capture Technologies led by the University of Nottingham, in conjunction with the University of Birmingham and Loughborough University in the Midlands Energy Consortium (MEC).[20] The Centre aims to produce the research leaders needed to tackle major national and international energy challenges over the next 15 years. Forty Research Engineers have started during the first 4 years of the EngD programme and, in total, over 50 EngDs will be produced. The Centre involves over 15 industrial partners and provides an excellent research environment for projects across chemistry, chemical engineering, materials, physics, mathematics and mechanical engineering. Thus, the Centre will make a major contribution to meeting the demand for

doctorates that are going to be required to support development and deployment of commercial-scale CCS.

The EngD Centre has also been engaged in a broad range of other activities in the broader UK energy research community and in encouraging international collaboration. These include:

membership of the recently formed Association of EngDs to ensure that best practice can be shared and also to help achieve accreditation from the relevant professional bodies;

taking the lead in establishing a Network for a handful of Energy Centres of Doctoral Training that aims to maximise quality and benefit of the various training programmes through coordinated activities;

two summer schools that have successfully raised the international profile of the EngD Centre; and

establishing an International Doctoral Innovation Centre at the University of Nottingham campus in Ningbo, which has transferred the CDT model to China.

3.2 UKCCSRC Community Network Early Career Researcher programme

An important insight from UK CCS Consortium activities in 2004-2009 was the value of engaging and supporting ECRs. The UKCCSRC Community Network, therefore, has a key aim to foster an interdisciplinary and supportive environment both for experienced academics and ECRs.[21] Nearly 150 of the 450 UKCCSRC Community Network members are ECRs. This demonstrates that developing a targeted programme for ECRs is laying the foundation for a better integrated CCS community both now and in the future in the UK.

The ECR Programme aims to:

equip ECRs with a good working knowledge of the whole CCS chain to complement their specialist studies;

introduce them to their peers across the country; and

facilitate the development of lasting relationships and collaborations. At the heart of this programme are two face-to-face annual meetings.

Important events in this programme are a Winter School for researchers new to CCS and a Summer Meeting attended by both new and more experienced ECRs. Nearly 100 CCS ‘newcomers’ have participated in the first two Winter School programmes which have facilitated direct links between ECRs and other key players in the CCS community including industry, government and regulators. The Network also supported activities to develop ECRs international research links and experience. Additionally, ECRs are still encouraged to participate in other aspects of the UKCCSRC programme such as biannual meetings of the whole UK CCS R&D community and the RAPID process.

The annual Winter School is often the first UKCCSRC-sponsored event that ECRs attend, and it aims to give attendees an overview of the whole CCS value chain. This wide perspective assists ECRs in understanding how and where their research fits into the CCS research scene, and allows them to network with a broad range of industrial, governmental, and academic speakers in a relaxed forum with their peers. The multi-day event also gives ECRs time to network amongst themselves, gaining insights into different programmes and areas of research outside their home institution. It also begins the process of building connections upon which future research collaborations may take place. The annual Summer Meeting builds on these initial links and also encourages networking across the broader ECR community

as a broader range of researchers typically attend. This regular event helps re-establish and strengthen connections, as well as giving ECRs a better understanding of the various programmes of CCS research being undertaken in the UK and further exposure to key stakeholders.

It is also important to encourage ECRs to establish international understanding and profile at an early stage. In addition to the domestic networking support mentioned above, the UKCCSRC Community Network provides programmes of financial support for ECRs to attend international meetings, participate in various international events such as summer schools, and undertake international exchanges. The Community Network has a designated programme for supporting ECRs wishing to engage in research at overseas academic institutions. It allows for week to month-long visits which allow ECRs to establish or strengthen collaborations and gain skills and insights from host institutions. The exchange programme also facilitates ECRs from other countries to come to the UK, bringing in talented individuals who are keen to work with UK researchers on various topics within the CCS value chain.

In addition to the exchange programme, the Network works with a range of institutions and organisations to enhance UK participation in a broader range of international progammes. In 2010 and 2011, the Network funded placements for three non-EngD post-graduates to attend summer schools in India and China, respectively, organised by the EngD Centre in Fossil Energy and Carbon Capture Technologies (Section 3.1). In 2012, the Network co-sponsored the IEAGHG Student Mentoring Programme at GHGT-11, allowing 10 UK post-graduate students to attend this prestigious conference, interact with other CCS students from around the world and participate in a mentoring programme including one-to-one contact with some of the foremost international CCS researchers. Providing ECRs with meaningful research and networking experiences enhances their academic career and builds a stronger and coherent community.

4. Conclusions

This paper highlights key examples where the UK has and is actively building the national capacity in the CCS field. In particular, it introduces examples of co-ordinated research where ‘the sum is greater than the individual parts’ and outlines several activities that are investing for the future. As the UK CCS R&D community has expanded, core funding for the UK CCS Consortium, UK CCS Community Network and the recently-launched UK CCS Research Centre have helped to ensure that the UK academic community is able to work collaboratively to develop innovative ideas to support effective deployment of CCS. The PACT facilities (Section 2.1) provide a unique pilot-scale resource and the RAPID process (Section 2.3) will help to ensure that researchers focus on key problems of relevance to the broader stakeholder community. The CCPilot100+ pilot project (Section 2.2) provides an excellent example of the potential to leverage a ‘real world’ industrial project to develop advanced skills and understanding, providing benefits for both industry and academic participants. Innovative postgraduate training for both taught and research postgraduates (Section 3.1) complemented by a dedicated ECR programme for networking within the UK and building international links (Section 3.2) is also expected to contribute to a strong base of professionals able to work together to deliver effective CCS innovation and deployment in the UK and globally.

Acknowledgements

The authors gratefully acknowledge financial support for the UK CCS Consortium, UK CCS Community Network and UK CCS Research Centre from the RCUK Energy Programme. We would also like to thank Mark Wilkinson and Feargal Brennan for sharing information about the MSc programmes at the University of Edinburgh and Cranfield University respectively, and Jeremy Carey, Mathieu Lucquiaud, and Olivia Errey, for sharing information on the CCPilot100+ programme. The information and opinions expressed in this paper are, however, entirely the responsibility of the authors.

References

[1] Holloway S, Savage D. The potential for aquifer disposal of carbon-dioxide in the UK. *Energy Conversion and Management* 1993; **34**:925-32.
[2] Royal Commission on Environmental Pollution. Energy – The Changing Climate. (http://www.rcep.org.uk/energy.htm) June 2000
[3] DTI. Our Energy Future – Creating A Low Carbon Economy. HMSO, White Paper. Feb 2003.
[4] IPCC, - Bert Metz, Ogunlade Davidson, Heleen de Coninck, Manuela Loos and Leo Meyer (Eds.). Carbon Dioxide Capture and Storage. Cambridge University Press, UK. 2005; pp 431.
[5] Gibbins, J. Progress with the UK Carbon Capture and Storage Consortium. *Energy Procedia* 2009; 1; 4681-7.
[6] http://www.publications.parliament.uk/pa/ld200708/ldselect/ldeconaf/195/195we67.htm
[7] International Energy Agency. Technology Roadmap: Carbon Capture and Storage. 2009; pp52.
[8] Committee for Climate Change. Meeting Carbon Budgets – 2012 Progress Report to Parliament. 2012; pp 286
[9] ETI. Press Release. (http://www.eti.co.uk/news/article/ed_davey_announces_new_20_million_eti_project_set_to_advance_carbon_capture) 11 Oct. 2012.
[10] Williams, J. Presentation at UKCCSRC Meeting. (http://www.ukccsrc.ac.uk/system/files/uploads/Jacqui%20Williams.pdf) Sept 2012.
[11] DECC. CCS Roadmap – Supporting deployment of Carbon Capture and Storage in the UK. (http://www.decc.gov.uk/assets/decc/11/cutting-emissions/carbon-capture-storage/4899-the-ccs-roadmap.pdf) April 2012.
[12] http://www.ukccsrc.ac.uk/acttrom-0
[13] SSE. Presentation. (http://www.sse.com/uploadedFiles/Z_Microsites/Ferrybridge/Controls/Lists/Resources/CCPilot100+Brochure.pdf)
[14] UKCCSRC. RAPID Handbook, (http://www.ukccsrc.ac.uk/system/files/RAPID_HANDBOOK_Phase1_24July12final2.pdf) June 2012.
[15] APGTF, Cleaner Fossil Power Generation in the 21st Century – Maintaining a Leading Role
a technology strategy for fossil fuel carbon abatement technologies. (http://www.apgtf-uk.com/) Aug 2011.
[16] http://www.ed.ac.uk/schools-departments/geosciences/postgraduate/masters-programme/taught-masters/carbon-capture-storage/about-msc-ccs/overview
[17] http://www.cranfield.ac.uk/soe/postgraduatestudy/carboncapture/index.html
[18] http://www.epsrc.ac.uk/funding/students/centres/current/Pages/energy.aspx
[19] http://www.epsrc.ac.uk/funding/students/centres/Pages/centres.aspx
[20] http://www.efetedc.ac.uk/efet/index.aspx
[21] http://www.ukccsc.co.uk/early-career/